Better Vision for Better Learning?: Evidence from a Randomized Controlled Trial in Vietnam

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Background and Motivation

- Lack of information on global childhood vision impairment (VI)

- Globally, 19M under age 15 vision impaired in 2010
  $\Rightarrow$ 12M among them: uncorrected refractive errors (RE)

- VI of children: health problem + obstacle to learning

- RE can be easily corrected with eyeglasses
  $\Rightarrow$ Eyeglasses - unaffordable/inaccessible in LMIC (Karnani et al. 2011)
  $\Rightarrow$ Many eyeglasses projects for children in LMIC

- Little literature on the effect of providing eyeglasses

Literature Review (1/2)

- Zhao et al. (2000)- China data (Children aged 5-15)
    - Prevalence of RE and VI in school-aged children
    - 13% VI $\Rightarrow$ 90% due to RE
    - No study of how RE/VI affect children's education

- Yi et al. (2015)- China data (Grade 4-5 students)
    - Prevalence of VI in school-aged children
    - 24% VI in either eye & 16% VI in both eyes
    - 1 LogMAR $\downarrow$ $\Rightarrow$ 0.1 SD $\downarrow$ in math
    - Severe VI $\Rightarrow$ 0.3 SD $\downarrow$ in math
    - No study of the link to other subjects (such as reading skills)
    - No study of the effect of providing eyeglasses

Literature Review (2/2)

- Ma et al. (2014)- China data (Grade 4-5 students)
    - Educational effect of providing eyeglasses using RCT
    - 36 % had RE / 15% had eyeglasses
    - Providing eyeglasses $\Rightarrow$ 0.11 SD $\uparrow$ in math (1 year)

- Glewwe, Park, and Zhao (2016)- China data (Grade 4-6 students)
    - Educational effect of providing eyeglasses using RCT
    - 12 % of the school-age children had VI due to RE
    - Providing eyeglasses $\Rightarrow$ 0.16-0.22 SD $\uparrow$ in test scores (1 year)

- Glewwe, West, and Lee (2018)- USA data (Grade 4-6 students)
    - Educational effect of eye exam & providing eyeglasses / RCT
    - 27% had untreated vision problem
    - Eye exam + eyeglasses $\Rightarrow$ 2%p $\uparrow$ pass reading & math test (FCAT)

This study

- Prevalence of vision impairment of school-age children

- Impact of providing eyeglasses on academic performance
    - Grade 4-5 students in Vietnam
    - Reading and mathematics tests

- Randomized Controlled Trial (RCT)
    - School-level RCT
    - Phase-in design

- Randomization inference
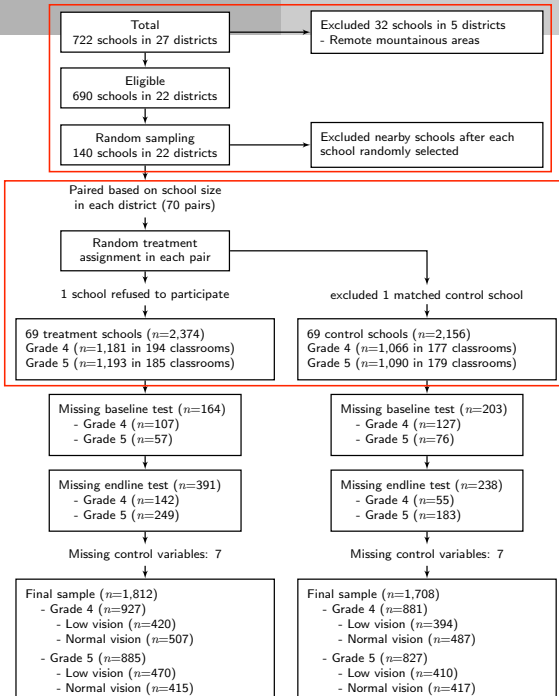
- Multiple-test procedure

Vietnam

- One of the world's fastest growing economies
    - Real GDP: \$232B (2002) $\xrightarrow{x2.4}$ \$552B (2012)

    - Poverty rate: 38.0% (2002) $\implies$ 2.8% (2012)

- Limited eye health care services / eye health professionals
    - Especially for children
    - 10-20% of school-age children had RE (VN Ministry of Health, 2007)
    - 20% aged 12-15 in Southern VN / 39% in HCMC area (Paudel et al. 2014)
    - 36% of childhood blindness due to uncorrected RE (Limburg et al. 2012)

Project Overview

- The Blindness Zero Movement Project (Project BOM)

    - School-based vision screening & eyeglasses program

    - Thanh Hoa province in Vietnam / 2016-17 academic year

    - Grades 4 and 5 in 140 primary schools in 22 districts

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┌─────────────────────────┐        ┌──────────────────────────────┐
│ Total                   │───────→│ Excluded 32 schools in 5 districts │
│ 722 schools in 27 districts │     │ - Remote mountainous areas    │
└─────────────────────────┘        └──────────────────────────────┘
            ↓
┌─────────────────────────┐
│ Eligible                │
│ 690 schools in 22 districts │
└─────────────────────────┘
            ↓
┌─────────────────────────┐        ┌──────────────────────────────┐
│ Random sampling         │───────→│ Excluded nearby schools after each │
│ 140 schools in 22 districts │     │ school randomly selected      │
└─────────────────────────┘        └──────────────────────────────┘
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Paired based on school size
in each district (70 pairs)

Random treatment
assignment in each pair

1 school refused to participate   excluded 1 matched control school

69 treatment schools (n=2,374)   69 control schools (n=2,156)
Grade 4 (n=1,181 in 194 classrooms)   Grade 4 (n=1,066 in 177 classrooms)
Grade 5 (n=1,193 in 185 classrooms)   Grade 5 (n=1,090 in 179 classrooms)

Missing baseline test (n=164)   Missing baseline test (n=203)
- Grade 4 (n=107)   - Grade 4 (n=127)
- Grade 5 (n=57)   - Grade 5 (n=76)

Missing endline test (n=391)   Missing endline test (n=238)
- Grade 4 (n=142)   - Grade 4 (n=55)
- Grade 5 (n=249)   - Grade 5 (n=183)

Missing control variables: 7   Missing control variables: 7

Final sample (n=1,812)   Final sample (n=1,708)
- Grade 4 (n=927)   - Grade 4 (n=881)
  - Low vision (n=420)   - Low vision (n=394)
  - Normal vision (n=507)   - Normal vision (n=487)
- Grade 5 (n=885)   - Grade 5 (n=827)
  - Low vision (n=470)   - Low vision (n=410)
  - Normal vision (n=415)   - Normal vision (n=417)

Randomization

- 722 primary schools in 27 districts $\Rightarrow$ 140 schools in 22 districts

- Step 1: Random school selection
    - 5 districts (32 schools) in remote mountainous areas excluded
    - 140 schools selected proportionally with # schools in each district

- Step 2: Random treatment assignment
    - Paired in each district based on school size
    - Each pair $\Rightarrow$ 1 treatment school & 1 control school
    - 70 treatment schools & 70 control schools

- Study sample: 138 schools (69 treatment & 69 control)
    - 1 treatment school refused to participate
    - Excluded 1 matched control school

School Vision Screening and Data Collection

- Baseline (October - November 2016)
  - Day 1- Eye examination
  - Day 2 - Baseline tests (Reading & Mathematics)

- Endline (October 2017)
  - Endline tests (Reading & Mathematics)

Vision Screening and Implementation

- 2-step vision screening: grade 4 & 5 students

- Step 1: Preliminary vision screening (school teachers)
    - Teacher training workshop
    - Vision screening (eye chart) / visual acuity (VA) < 6/9
    - 23,500 students vision screened (October 2016)
    - 3,500 students failed

- Step 2: Comprehensive vision exam (eye health professionals)
    - 3,485 failed + 1,389 passed $\Rightarrow$ 4,874 students examined
    - 3,485 failed $\Rightarrow$ 2,522 students (72.4 %) VI
    - 1,389 passed $\Rightarrow$ all normal vision

Table 1. Vision Screening Results

Myopia only	1,747 (7.44%)	Myopia 2,027 (8.64%)	Astigmatism 647 (2.76%)	Refractive errors 2,456 (10.46%)	Vision impairments 2,522 (10.74%)	Total students screened 23,474 (100%)
Myopia + astigmatism	279 (1.19%)					
Astigmatism only	349 (1.49%)					
Hyperopia + astigmatism	18 (0.07%)	Hyperopia 81 (0.35%)				
Hyperopia only	62 (0.26%)					
Myopia + hyperopia + astigmatism	1 (0.004%)					
Other vision impairments	66 (0.28%)					
Normal vision	20,952 (89.26%)					

Note: Among 2,456 students who had refractive errors, 671 (27.3%) already had eyeglasses. However, only 197 (29.4%) among the 671 students had appropriate eyeglasses. Thus, the number of students who had uncorrected refractive errors was 2,259 (9.6%). One student had myopia in one eye and hyperopia in the other.

Data

- 2,456 students w/ RE $\Rightarrow$ 2,307 students included in the study
  - Uncorrected RE: 2,134 $\Rightarrow$ Low-vision group
  - Corrected RE: 173 $\Rightarrow$ Normal-vision group

- 2,352 students w/ normal vision $\Rightarrow$ 2,223 students included

$\Rightarrow$ Study sample
  - Low-vision student: 2,134 (= 2,307 - 173)
  - Normal-vision student: 2,396 (= 2,223 + 173)

Table 3. Participants in the Study

Group		Number of schools	Number of classrooms	Number of students		
				Low vision	Normal vision	Total
Treatment	Grade 4		194	522	659	1,181
	Grade 5	69	185	618	575	1,193
	Total		379	1,140	1,234	2,374
Control	Grade 4		177	454	612	1,066
	Grade 5	69	179	540	550	1,090
	Total		356	994	1,162	2,156
Total	Grade 4		371	976	1,271	2,247
	Grade 5	138	364	1,158	1,125	2,283
	Total		735	2,134	2,396	4,530

Note: One treatment school refused to participate in the study, so the refused treatment school and its paired control school were excluded from the study. Among 612 students who already had eyeglasses, 173 students whose vision was already corrected with appropriate eyeglasses were classified as normal-vision students, so 86 students (31 in grade 4 and 55 in grade 5) in the treatment schools and 87 students (42 in grade 4 and 45 in grade 5) in the control schools were included as normal-vision students in the study.
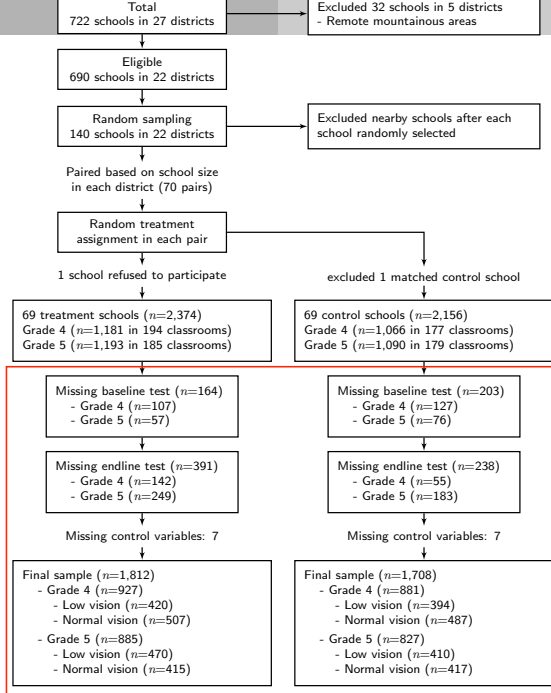
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                    Total                        Excluded 32 schools in 5 districts
           722 schools in 27 districts           - Remote mountainous areas

                  Eligible
          690 schools in 22 districts

             Random sampling                 Excluded nearby schools after each
          140 schools in 22 districts        school randomly selected

       Paired based on school size
        in each district (70 pairs)

            Random treatment
         assignment in each pair

    1 school refused to participate          excluded 1 matched control school

  69 treatment schools (n=2,374)             69 control schools (n=2,156)
  Grade 4 (n=1,181 in 194 classrooms)        Grade 4 (n=1,066 in 177 classrooms)
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Table 5. Balance Tests

Individual level variables	Treatment schools ($N = 1,812$) Mean (SD)	Control schools ($N = 1,708$) Mean (SD)	t-test p-value	Joint balance test ($N = 3,520$) Coef. (SE)	F-test
Reading raw scores at baseline (0~30)	18.27 (5.39)	18.20 (5.16)	0.842	0.002 (0.003)	
Math raw scores at baseline (0~30)	15.41 (5.40)	15.43 (5.18)	0.873	-0.001 (0.003)	
Girl	0.494 (0.50)	0.489 (0.50)	0.608	0.002 (0.012)	$F_{6,137} = 0.84$
Age (in years)	10.75 (0.61)	10.73 (0.62)	0.478	0.024 (0.019)	(p-value = 0.540)
Height (cm)	132.68 (7.46)	133.24 (7.70)	0.135	-0.004* (0.002)	
Uncorrected refractive errors	0.491 (0.50)	0.471 (0.50)	0.380	0.015 (0.014)	
Refractive errors	0.528 (0.50)	0.513 (0.50)	0.564		
Myopia	0.442 (0.50)	0.420 (0.49)	0.301		
Hyperopia	0.018 (0.13)	0.022 (0.15)	0.282		
Astigmatism	0.137 (0.34)	0.131 (0.34)	0.874		

School level variables	Treatment schools ($N = 69$ schools) Mean (SD)	Control schools ($N = 69$ schools) Mean (SD)	t-test p-value	Joint balance test ($N = 138$ schools) Coef. (SE)	F-test
Grade 4 size (total number of students in grade 4)	89.09 (40.86)	81.65 (27.86)	0.086	0.010* (0.005)	$F_{2,137} = 3.22$
Grade 5 size (total number of students in grade 5)	84.48 (39.63)	79.75 (35.41)	0.212	-0.003 (0.005)	(p-value = 0.043)

Note: The p-values reported in the third column is from the t-test of the null hypothesis H_0: $\beta = 0$ in the regressions: variable $= \alpha + \beta \times$ (treatment) + Dummies for matched pair $+ \epsilon$. The F-test for the joint balance test is used to test the null hypothesis that $\beta_i = 0 \; \forall i \in \{1, \cdots, I\}$ in the regression: treatment $= \alpha + \sum_{i=1}^{I} \beta_i \times$ (variable$_i$) + Dummies for matched pair $+ \epsilon$. The standard errors are clustered at the school level.
*** $p<0.01$; ** $p<0.05$; * $p<0.1$.

Density Plot of Baseline Test Scores
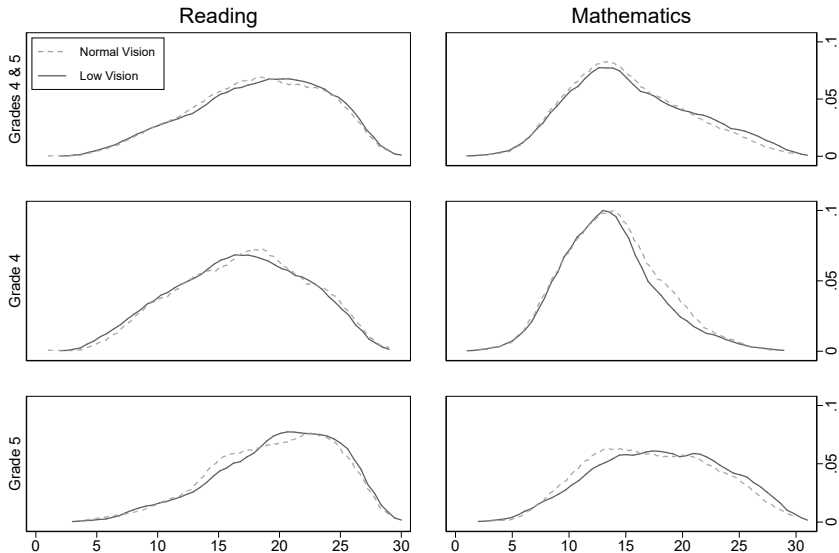
School-Level Cluster RCT

- Reasons to use school-level RCT over individual-level RCT
    - Ethical issues: equality within school & between schools
    - Political issues
    - Logistic and cost issues

- Partial compliance
    - In treatment schools
    - In control schools
    - Intention-to-treat (ITT) analysis

- School-level cluster RCT
- Phased-in design $\Rightarrow$ Providing eyeglasses to control schools

Empirical Strategy (1/5)

$$Y_{is} = \alpha + \beta T_s + \sum_j \lambda_j P_s^j + u_{is} \tag{1}$$

$$\begin{cases} Y_{is} : & \text{outcome of interest for student i in school s} \\ T_s = 0 : & \text{if school s is randomly assigned control school} \\ T_s = 1 : & \text{if school s is randomly assigned treatment school} \\ P_s^j : & \text{dummies for randomization pair } \text{(Bruhn and McKenzie 2009)} \end{cases}$$

Randomization $\Rightarrow T_s$ is uncorrelated with u_{is}

$\Rightarrow \beta$ is unbiased ITT estimates

(Note: This estimation uses students only with **low vision**.)

Empirical Strategy (2/5)

$$Y_{is} = \alpha + \beta T_s + \sum_j \lambda_j P_s^j + u_{is} \tag{1}$$

- With normal-vision sample

  $\Rightarrow \beta$: Spillover effect on normal-vision students in treatment schools

Empirical Strategy (3/5)

- Some baseline characteristics are not balanced.

- Need to add unbalanced control variables
  - $\Rightarrow$ to avoid potential bias
  - $\Rightarrow$ to increase precision

- Adding control variables:

$$Y_{is} = \alpha + \beta T_s + \mathbf{X'_{is}}\gamma + \sum_j \lambda_j P_s^j + u_{is} \qquad (2)$$

(Note: This estimation uses students only with **low vision**.)

Empirical Strategy (4/5)

$$Y_{is} = \alpha + \beta T_s + \delta B_i + \eta T_s \cdot B_i + \textbf{\textit{X}}'_{\textbf{\textit{is}}}\gamma + \sum_j \lambda_j P_s^j + u_{is}, \tag{3}$$

where B_i is a dummy variable indicates 'Low Vision'

- η: treatment effect of providing eyeglasses for low-vision students
- β: spillover effect for normal-vision students in treatment schools
- δ: possible link between uncorrected RE and outcome

(Note: This estimation uses students with **low** or **normal vision**.)

Empirical Strategy (5/5)

- Standard errors are clustered at the school level.

- *p*-values are adjusted based on randomization inference.
  - Permute treatment re-assignment 1,000 times
  - Stratify randomization pair & cluster at school level
  - Test H0: Treatment effect is by chance (Athey and Imbens 2017; Heß 2017)

- *q*-values to control for FDR are also reported (Newson 2010; Simes 1986).
  - Multiple-test procedure
  - Compare *p*-values of treatment in 6 models for each outcome
    - 3 simple models without control variables (not reported)
    - 3 main models with control variables (used in this study)

Table 6. The Effect of Providing Eyeglasses on Academic Performance (Low-Vision Sample)

	Total score at endline			Reading score at endline			Math score at endline		
	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment	0.195***	0.256***	0.139**	0.158***	0.217***	0.089	0.179***	0.226**	0.156***
	(0.047)	(0.068)	(0.054)	(0.043)	(0.059)	(0.057)	(0.052)	(0.089)	(0.056)
R.I. *p*-value	[0.002]	[0.000]	[0.055]	[0.007]	[0.003]	[0.230]	[0.011]	[0.052]	[0.043]
q-value	{0.000}	{0.001}	{0.023}	{0.001}	{0.001}	{0.181}	{0.005}	{0.024}	{0.017}
Reading score at baseline	0.496***	0.568***	0.397***	0.570***	0.587***	0.537***	0.307***	0.388***	0.194***
	(0.028)	(0.042)	(0.035)	(0.030)	(0.040)	(0.043)	(0.029)	(0.049)	(0.034)
Math score at baseline	0.367***	0.331***	0.427***	0.156***	0.151***	0.173***	0.500***	0.460***	0.568***
	(0.031)	(0.046)	(0.036)	(0.030)	(0.039)	(0.045)	(0.032)	(0.055)	(0.032)
Grade 5	-0.205**			0.118			-0.524***		
	(0.095)			(0.094)			(0.099)		
Age	-0.146**	-0.021	-0.196**	-0.159**	-0.072	-0.243***	-0.115*	0.017	-0.114
	(0.071)	(0.119)	(0.076)	(0.074)	(0.116)	(0.092)	(0.069)	(0.118)	(0.075)
Female	0.168***	0.248***	0.075	0.210***	0.293***	0.104*	0.080*	0.13	0.035
	(0.042)	(0.069)	(0.050)	(0.044)	(0.061)	(0.062)	(0.046)	(0.082)	(0.053)
Height	0.019***	0.022***	0.015***	0.012***	0.014***	0.009**	0.022***	0.026***	0.018***
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.004)	(0.003)	(0.007)	(0.003)
Grade size	-0.002	-0.002	-0.002	-0.000	-0.000	-0.000	-0.003**	-0.004	-0.002*
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.003)	(0.001)
Randomization pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1694	814	880	1694	814	880	1692	812	880
R-squared	0.552	0.550	0.641	0.490	0.520	0.532	0.486	0.461	0.591

Note: Reading and math test scores are standardized separately for each grade using the test scores of control school students at baseline. The randomization pair-level strata fixed effects are included in all regression models, and standard errors in parentheses are clustered at the school level. Randomization inference *p*-values, clustered by school and stratified by stratification pair, are in brackets. Simes (1986) *q*-values for the multiple hypothesis testing are in braces.
*** *p*<0.01; ** *p*<0.05; * *p*<0.1.

Table 7. Spillover Effects of Providing Eyeglasses (Normal-Vision Sample)

	Total score at endline			Reading score at endline			Math score at endline		
	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment	-0.062	-0.032	-0.101*	-0.031	0.017	-0.122**	-0.090	-0.084	-0.061
	(0.055)	(0.082)	(0.057)	(0.050)	(0.074)	(0.060)	(0.058)	(0.089)	(0.061)
R.I. p-value	[0.417]	[0.765]	[0.201]	[0.653]	[0.840]	[0.135]	[0.261]	[0.473]	[0.458]
q-value	{0.766}	{0.966}	{0.488}	{0.824}	{0.824}	{0.257}	{0.552}	{0.552}	{0.552}
Reading score at baseline	0.445***	0.480***	0.317***	0.481***	0.479***	0.439***	0.300***	0.341***	0.141***
	(0.030)	(0.038)	(0.039)	(0.031)	(0.040)	(0.044)	(0.033)	(0.045)	(0.041)
Math score at baseline	0.344***	0.250***	0.521***	0.188***	0.123***	0.288***	0.427***	0.338***	0.624***
	(0.033)	(0.044)	(0.037)	(0.028)	(0.040)	(0.038)	(0.038)	(0.051)	(0.041)
Grade 5	-0.331***			0.003			-0.643***		
	(0.091)			(0.095)			(0.092)		
Age	-0.101	-0.088	-0.084	-0.146**	-0.146	-0.125	-0.032	0.010	-0.048
	(0.062)	(0.087)	(0.092)	(0.065)	(0.089)	(0.097)	(0.066)	(0.097)	(0.090)
Female	0.141***	0.187***	0.102*	0.210***	0.252***	0.167**	0.029	0.051	0.025
	(0.042)	(0.061)	(0.058)	(0.045)	(0.068)	(0.064)	(0.046)	(0.064)	(0.062)
Height	0.014***	0.013**	0.012***	0.012***	0.009*	0.012***	0.013***	0.015**	0.009**
	(0.003)	(0.006)	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.007)	(0.004)
Grade size	0.001	0.002	0.003*	0.001	0.002	0.003*	0.001	0.001	0.002
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Randomization pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,826	994	832	1,825	994	831	1,825	994	831
R-squared	0.501	0.492	0.600	0.433	0.445	0.511	0.443	0.411	0.543

Note: Reading and math test scores are standardized separately for each grade using the test scores of control school students at baseline. The randomization pair-level strata fixed effects are included in all regression models, and standard errors in parentheses are clustered at the school level. Randomization inference p-values, clustered by school and stratified by stratification pair, are in brackets. Simes (1986) q-values for the multiple hypothesis testing are in braces.
   $^{***}p<0.01$; $^{**}p<0.05$; $^{*}p<0.1$.

Table 8. The Effect of Providing Eyeglasses on Academic Performance (Full Sample with Low- and Normal-Vision Students)

| | Total score at endline | | | Reading score at endline | | | Math score at endline | | |
| | Grades 4 & 5 | Grade 4 | Grade 5 | Grades 4 & 5 | Grade 4 | Grade 5 | Grades 4 & 5 | Grade 4 | Grade 5 |
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment	-0.045	-0.001	-0.071	-0.019	0.032	-0.084	-0.070	-0.046	-0.044
	(0.056)	(0.081)	(0.063)	(0.052)	(0.073)	(0.066)	(0.059)	(0.089)	(0.064)
R.I. p-value	[0.561]	[0.992]	[0.358]	[0.784]	[0.721]	[0.328]	[0.373]	[0.697]	[0.580]
q-value	{0.989}	{0.989}	{0.989}	{0.972}	{0.972}	{0.972}	{0.724}	{0.724}	{0.724}
Low vision	-0.026	-0.100[*]	0.061	0.017	-0.054	0.100[*]	-0.060	-0.120	0.009
	(0.039)	(0.060)	(0.046)	(0.039)	(0.059)	(0.058)	(0.047)	(0.074)	(0.044)
R.I. p-value	[0.961]	[0.018]	[0.984]	[0.997]	[0.403]	[0.969]	[0.355]	[0.030]	[0.983]
q-value	{0.610}	{0.192}	{0.274}	{0.660}	{0.430}	{0.270}	{0.306}	{0.217}	{0.836}
Treatment × Low vision	0.212[***]	0.220[***]	0.184[**]	0.168[***]	0.184[**]	0.156[*]	0.204[***]	0.203[**]	0.168[**]
	(0.063)	(0.082)	(0.080)	(0.059)	(0.078)	(0.085)	(0.071)	(0.102)	(0.080)
R.I. p-value	[0.005]	[0.007]	[0.036]	[0.004]	[0.028]	[0.069]	[0.009]	[0.057]	[0.046]
q-value	{0.006}	{0.024}	{0.044}	{0.030}	{0.058}	{0.137}	{0.029}	{0.097}	{0.097}
Test Scores at baseline	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Randomization pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,520	1,808	1,712	3,519	1,808	1,711	3,517	1,806	1,711
R-squared	0.512	0.497	0.601	0.446	0.457	0.498	0.449	0.410	0.549

Note: Reading and math test scores are standardized separately for each grade using the test scores of control school students at baseline. The randomization pair-level strata fixed effects are included in all regression models, and standard errors in parentheses are clustered at the school level. Randomization inference p-values, clustered by school and stratified by stratification pair, are in brackets. Simes (1986) q-values for the multiple hypothesis testing are in braces.
  [***]$p<0.01$; [**]$p<0.05$; [*]$p<0.1$.

Results by Sub-Group: Gender

$$
\begin{aligned}
Y_{is} &= \alpha + \delta B_i + \theta B_i \cdot (\text{Girl})_i \\
&\quad + \eta_1 T_s \cdot B_i \cdot (\text{Girl})_i + \eta_2 T_s \cdot B_i \cdot (\text{Boy})_i \\
&\quad + \eta_3 T_s \cdot (1 - B_i) \cdot (\text{Girl})_i + \eta_4 T_s \cdot (1 - B_i) \cdot (\text{Boy})_i \\
&\quad + \boldsymbol{X'_{is}}\gamma + \sum_j \lambda_j P_s^j + u_{is}
\end{aligned}
$$

$$
\left\{
\begin{array}{rl}
(\text{Girl})_i : & \text{dummy indicates girl} \\
(\text{Boy})_i : & \text{dummy indicates boy} \\
B_i : & \text{dummy indicates low vision} \\
(1 - B_i) : & \text{dummy indicates normal vision}
\end{array}
\right.
$$

Table 9. The Effect of Providing Eyeglasses on Academic Performance by Gender (Full Sample with Low- and Normal-Vision Students)

	Total score at endline			Reading score at endline			Math score at endline		
	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment × Low vision × Boy	0.203***	0.278***	0.118	0.196***	0.305***	0.070	0.133*	0.142	0.131
	(0.068)	(0.096)	(0.079)	(0.065)	(0.087)	(0.082)	(0.075)	(0.113)	(0.083)
R.I. p-value	[0.005]	[0.017]	[0.201]	[0.004]	[0.005]	[0.387]	[0.127]	[0.300]	[0.186]
q-value	{0.013}	{0.013}	{0.205}	{0.009}	{0.004}	{0.468}	{0.345}	{0.42}	{0.345}
Treatment × Low vision × Girl	0.134**	0.146	0.110	0.106*	0.112	0.072	0.136*	0.165	0.120
	(0.062)	(0.099)	(0.071)	(0.058)	(0.086)	(0.080)	(0.071)	(0.129)	(0.073)
R.I. p-value	[0.041]	[0.149]	[0.198]	[0.094]	[0.206]	[0.424]	[0.076]	[0.249]	[0.175]
q-value	{0.194}	{0.25}	{0.25}	{0.411}	{0.455}	{0.455}	{0.302}	{0.302}	{0.302}
Treatment × Normal vision × Boy	-0.112	-0.041	-0.164*	-0.074	0.003	-0.153*	-0.129	-0.089	-0.129
	(0.072)	(0.104)	(0.086)	(0.064)	(0.091)	(0.086)	(0.079)	(0.118)	(0.088)
R.I. p-value	[0.212]	[0.752]	[0.092]	[0.341]	[0.973]	[0.120]	[0.208]	[0.542]	[0.210]
q-value	{0.36}	{0.831}	{0.357}	{0.759}	{0.971}	{0.465}	{0.443}	{0.604}	{0.443}
Treatment × Normal vision × Girl	0.034	0.045	0.040	0.045	0.065	-0.001	-0.001	0.004	0.057
	(0.065)	(0.096)	(0.081)	(0.072)	(0.105)	(0.096)	(0.066)	(0.097)	(0.087)
R.I. p-value	[0.660]	[0.699]	[0.699]	[0.594]	[0.642]	[0.642]	[0.984]	[0.965]	[0.965]
q-value	{0.684}	{0.684}	{0.684}	{0.81}	{0.81}	{0.993}	{0.984}	{0.984}	{0.984}
Test Scores at baseline	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Randomization pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,520	1,808	1,712	3,519	1,808	1,711	3,517	1,806	1,711
R-squared	0.512	0.498	0.602	0.446	0.458	0.499	0.449	0.410	0.550

Note: Reading and math test scores are standardized separately for each grade using the test scores of control school students at baseline. The randomization pair-level strata fixed effects are included in all regression models, and standard errors in parentheses are clustered at the school level. Randomization inference p-values, clustered by school and stratified by stratification pair, are in brackets. Simes (1986) q-values for the multiple hypothesis testing are in braces. The interaction term "Low vision × Female" in addition to the single term "Low vision" and "Female" are also included in the regression model.
***p<0.01; **p<0.05; *p<0.1.

Results by Sub-Group: Vision Impairment

- Vision Impairment (VI) Level
  - Normal vision: VA $> 6/9$
  - Mild VI: $6/9 \geq$ VA $> 6/18$
  - Moderate/Severe VI: $6/18 \geq$ VA

$$
\begin{aligned}
Y_{is} &= \alpha + \sum_{j=1}^{2} \delta_j (\text{VI})_{ij} + \eta_0 \, T_s \cdot (\text{VI})_{i0} + \eta_1 \, T_s \cdot (\text{VI})_{i1} + \eta_2 \, T_s \cdot (\text{VI})_{i2} \\
&\quad + \boldsymbol{X}_{is}' \gamma + \sum_j \lambda_j P_s^j + u_{is}
\end{aligned}
$$

$$
\begin{cases}
(\text{VI})_{i0} : & \text{dummy indicates normal vision} \\
(\text{VI})_{i1} : & \text{dummy indicates mild VI} \\
(\text{VI})_{i2} : & \text{dummy indicates moderate/severe VI}
\end{cases}
$$

Table 10. Treatment Effect of Providing Eyeglasses on Academic Performance by Baseline Vision Impairment (VI) Level (Full Sample with Low- and Normal-Vision Students)

	Total score at endline			Reading score at endline			Math score at endline		
	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5	Grades 4 & 5	Grade 4	Grade 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment × Normal Vision	0.015	0.076	-0.036	0.036	0.116*	-0.061	-0.026	-0.001	-0.013
	(0.053)	(0.079)	(0.056)	(0.047)	(0.069)	(0.058)	(0.057)	(0.088)	(0.059)
R.I. p-value	[0.847]	[0.445]	[0.624]	[0.564]	[0.167]	[0.402]	[0.748]	[0.996]	[0.868]
q-value	{0.923}	{0.923}	{0.923}	{0.533}	{0.342}	{0.533}	{0.995}	{0.995}	{0.995}
Treatment × Mild VI	0.027	-0.034	0.135	0.039	-0.021	0.152	0.021	-0.013	0.089
	(0.076)	(0.116)	(0.088)	(0.073)	(0.105)	(0.099)	(0.083)	(0.141)	(0.087)
R.I. p-value	[0.761]	[0.749]	[0.205]	[0.662]	[0.839]	[0.160]	[0.805]	[0.928]	[0.404]
q-value	{0.926}	{0.926}	{0.757}	{0.840}	{0.840}	{0.764}	{0.925}	{0.925}	{0.925}
Treatment × Moderate/Severe VI	0.180**	0.245**	0.100	0.140*	0.199**	0.039	0.169**	0.211	0.148*
	(0.078)	(0.114)	(0.076)	(0.074)	(0.100)	(0.082)	(0.085)	(0.136)	(0.082)
R.I. p-value	[0.030]	[0.038]	[0.274]	[0.070]	[0.051]	[0.679]	[0.057]	[0.161]	[0.121]
q-value	{0.100}	{0.100}	{0.304}	{0.180}	{0.180}	{0.639}	{0.222}	{0.247}	{0.222}
Test Scores at baseline	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Randomization pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,520	1,808	1,712	3,519	1,808	1,711	3,517	1,806	1,711
R-squared	0.510	0.499	0.598	0.443	0.458	0.496	0.448	0.411	0.547

Note: Reading and math test scores are standardized separately for each grade using the test scores of control school students at baseline. The randomization pair-level strata fixed effects are included in all regression models, and standard errors in parentheses are clustered at the school level. Randomization inference p-values, clustered by school and stratified by stratification pair, are in brackets. Simes (1986) q-values for the multiple hypothesis testing are in braces. The vision impairment (VI) level in this study is defined by adapting the International Classification of Diseases 11 (WHO 2018). Vision acuity (VA) better than 6/9 is defined as "Normal vision," while the threshold VA value is 6/12 in the International Classification of Disease 11 since the screening protocol of this project used 6/9 threshold to identify children with refractive errors. Accordingly, VA worse than 6/9, rather than 6/12, is defined as "Mild VI." VA worse than 6/18 is defined as "Moderate/Severe" VI as defined by the International Classification of Disease 11. Dummy variables for the VI levels, instead of the original dummy variable that indicates low vision or normal vision, are included in the regression models.
***p<0.01; **p<0.05; *p<0.1.

Discussion/Conclusion

- Robustness check
    - Corrected RE ⇒ Excluded

- First study investigates the effects of providing eyeglasses on academic performance in Vietnam

- Limited eye health care services for school-age children in VN
    - 10.7% VI & 9.6% uncorrected RE
    - 27% had eyeglasses ⇒ 29% appropriate eyeglasses (8% of RE)

- Providing eyeglasses ⇒ positive effect on academic performance
    - 0.16-0.22SD for reading & 0.16-0.23SD for math (after 1 year)
    - Grade 4 boys reading: 0.31SD ↑
    - Providing eyeglasses benefits moderate/severe VI students

- Further research
    - Factors affect refusal of wearing eyeglasses
    - Effect on non-cognitive skills and quality of life

Thank you

Questions?

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